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IN UPPER AIR RESEARCH

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P-760

February 15, 1956

Approved for OTS release

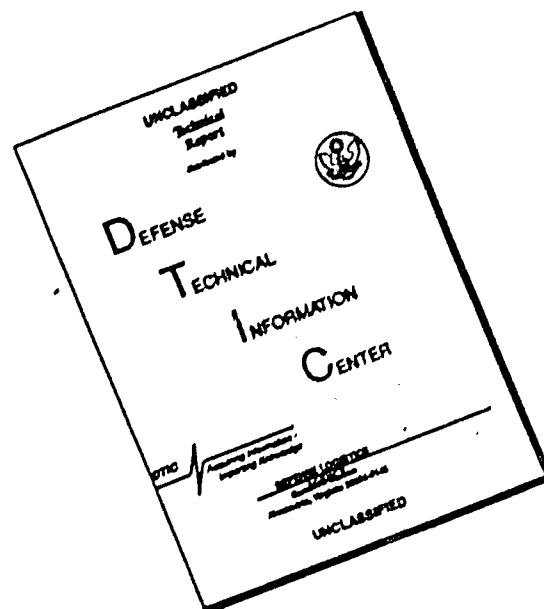
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Paper presented at the National Meeting of the  
American Meteorological Society held in New York,  
January 23, 1956.

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## USE OF AN ARTIFICIAL SATELLITE IN UPPER AIR RESEARCH

H. K. Kallmann and W. W. Kellogg

From the time President Eisenhower on July 29th of last year announced the launching within the near future of an artificial satellite, scientists from all over the world have indicated very great interest in the project. The artificial moon, as it also may be called, will be this country's most significant contribution to the global scientific effort which is planned for 1957-58.

Why are scientists so interested in such a spectacular and expensive undertaking? Before trying to answer that question, I should like to say a few words about the International Geophysical Year (IGY) program, of which the satellite program is only a part.

During this period the scientific efforts of some 40 nations will be co-ordinated to obtain observations on a world-wide scale, observations which will be vital to our scientific progress. Every effort is now being made to set up observation stations extending from pole to pole along certain meridians— $10^{\circ}$  East,  $140^{\circ}$  East, and  $750^{\circ}$  West longitudes—together with stations closely spaced around the equator and at the polar regions. Thus the observation and orbital tracking of an earth-circling vehicle will be greatly helped by these stations, particularly if the satellite is equipped with a simple radio transmitter which can contact these stations.

This country's effort in the world-wide program is being sponsored by the National Academy of Sciences, and is being guided by the U.S. National Committee for the IGY under the chairmanship of Professor Joseph Kaplan. Thirteen panels have been set up to direct the research in the different sciences related to problems in geophysics.

The principal fields of study will be solar activity, longitude and latitude, glaciology, oceanography, meteorology, geomagnetism, aurora and airglow, ionospheric physics, cosmic rays, seismology, and gravity. A large

portion of our program is in the hands of the Rocket Panel for purposes of high-altitude research. Some 600 rockets of various sizes which will reach altitudes up to 200 miles (approx. 320 km) will be fired from different locations. A separate panel will conduct the satellite program.

The programs of the other nations are being organized in a similar manner, although for most countries on a smaller scale, with the exception of the Russian program which in size is comparable to the U. S. program. However, no rocket research program and no satellite program has been submitted by the Soviet Union to the international committee as of today. France, England, Australia, and Japan, however, may undertake rocket research during the IGY.

Now, I should like to come back to the question as to why scientists want such an extravagant piece of equipment as an artificial satellite for their experiments and observations. Why can't they be satisfied with the observations made by means of rockets?

The answer is, that sounding rockets launched from a particular location at a particular time can give a vertical picture only of the atmosphere at a single instant of time, whereas most of the important observations to be made during the IGY are those which vary continuously with time, latitude, and longitude.

This picture (Fig. 1) is a schematic diagram of most of the important upper atmosphere problems. The same atmosphere which, by absorption, protects us from the powerful radiation coming from outside, is also the obstacle which hinders us from looking into outer space. In particular, the very important region of the ionosphere which is formed by the ultraviolet and X-ray radiation coming from the sun, acts as an "ion-curtain" beyond which we cannot see. And it is exactly this which we must do if we are to advance our knowledge of conditions on the earth and their dependence on conditions outside

the earth's atmosphere. A mere glimpse into space, as made by rockets, is not enough. We must look for an extended period of time from considerable altitudes in both directions—into space and towards the earth.

The types of data which can be collected by means of a geophysical satellite will vary with the available weight, power, and other features of the vehicle, such as auxiliary power supply and attitude stabilization.

There are two types of information which can be obtained from path observations alone; these are atmospheric densities and geodetic measurements. For these observations no instrumentation is required, although a light-weight radio transmitter of 5 to 10 pounds would be desirable. In any event, extremely accurate tracking of the vehicle in its orbit over several revolutions is essential. As the satellite circles the earth the air particles will gradually slow it down, so that it will eventually fall into the thicker layers of the lower atmosphere. Thus the altitude of the orbit will gradually change. Since the air drag is directly proportional to the square of the vehicle's speed and the atmospheric density, the drag effect can be used to determine air densities at these great heights.

A more accurate determination of the size and shape of the earth, and the distances between continents and islands, may be obtained if the artificial moon, rather than the real one, is used for geodetic measurements. The perturbation of the trajectory caused primarily by the oblateness of the earth will be larger on such a small vehicle operating close to the earth's surface, than it is on the large moon which is so much farther away. Again, accurate tracking from various stations along the path is essential.

Artificial seeding from the satellite, which means spraying known gases into the atmosphere, could serve a dual purpose. First, the tracking problem could be helped if the gas were to react with the air particles in such a way

as to produce visible light trails which could be seen from the ground.

Second, from spectroscopic observations of these light trails atmospheric composition could be deduced, since the gas ejected from the satellite obviously could react only with the air particles present at these high altitudes. No orientation or telemetering devices are needed for this experiment.

With a slightly larger payload for instrumentation—20 to 25 pounds for example—valuable meteor observations could be made. At present, meteors are observed from the ground by the visible light and ionization they cause when entering the earth's atmosphere at altitudes of 100 - 200 kilometers. High-speed telescopes, and radio or radar equipment, are used for observing these effects. It is obvious that enormous difficulties are encountered in determining the number and the masses and densities of meteors entering the earth's atmosphere per day on the basis of these rather limited observations. Also, telescopic cameras can cover only a small region of the sky at a time, and they are limited as to the order of magnitude or brightness to which they can see. Radar observations are hampered by the fact that in the case of small particles their paths must be perpendicular to the beam; otherwise no signal will be returned.

The impact of meteorites and micrometeorites on an artificial satellite can be measured by means of microphones placed along the skin of the vehicle. The number of pips observed in the telemetered record would give the number of dust particles encountered in a known area over a known period of time. There is recent evidence that more dust may enter our atmosphere than has been assumed. Then, also, there is the question of how much, if any, of the dust causing the zodiacal light drifts down to us.

Artificial meteors of known size, density, and velocity could be ejected from the satellite by means of shaped charges. Observations of the luminous

and ionization efficiency of these known particles when they enter the denser portions of the atmosphere would help in deducing masses and densities of real meteors coming from the solar system or from outer space.

Two obviously important applications of magnetic field measurements concern studies of cosmic rays and studies of the interactions between magnetic disturbances and the conditions in the ionosphere. Since the earth's magnetic field has an influence on moving charged particles, it is clear that it has an influence on incoming protons, alpha particles, and heavier ions which make up the primary cosmic rays.

There are very significant variations in the earth's magnetic field due to the complicated interactions between the motion of charges in the upper atmosphere and the geomagnetic field itself. It has frequently been pointed out that the winds in the ionosphere, which carry charged particles across the magnetic lines of force, cause the ionosphere to behave like an electric generator. The currents which are generated produce magnetic fields which are measured at the earth's surface as perturbations on the steady field. These perturbations become particularly noticeable during "magnetic storms," and may amount to as much as 10 per cent of the permanent component.

Simple and rugged total-field magnetometers based on nuclear resonance have been devised. Their extension to this problem appears to be relatively easy. Since the total field is involved, attitude stabilization is not critical, but some attention would have to be given to the magnetic moment of the vehicle itself.

Ever since cosmic rays were discovered some 40 years ago, the problem of the nature and origin of cosmic radiation has been one of the most intriguing in the field of physics. An answer to these questions might give a knowledge of the highest voltage generative force in the universe, and

perhaps even a better insight into the ancient question of the origin of the universe. A study of the behavior of primary cosmic ray particles would also further our understanding of the fundamental forces which bind sub-atomic particles.

Observations of primary particles as well as secondaries produced by the interaction with air particles, are made by means of cloud chambers, ionization chambers, Geiger counters, Geiger telescopes, and photographic emulsions. The latter requires physical recovery of the film, while the former methods require telemetering of the observations.

To date, reflection of sunlight by the earth has been calculated from estimates of reflection from clouds, oceans, snow fields, forests, etc., or by the earthshine reflected from the moon. These techniques, useful as they are, have serious limitations, as has been pointed out by Dr. Fritz. A satellite vehicle would have an unobstructed view of the earth and sky, so that the radiation reaching the earth from the sun, and the radiation reflected from the earth back into space, could be measured.

The measurements taken from a bolometer pointing toward the sun would provide a direct determination of the so-called solar constant and its possible variation. The measurement of the incoming energy, the reflected and back-scattered energy, and the outgoing long-wave radiation would provide the necessary energy data for studies of the thermodynamic state of the earth and its atmosphere—a problem of great importance to the meteorologist.

Last but not least, I would like to discuss the importance of ultra-violet and X-ray measurements from an artificial satellite. It is this radiation coming from the sun and its atmosphere, the chromosphere and the corona, which is completely absorbed by our atmosphere and which therefore cannot be observed from the surface of the earth. On the other hand, it



is this radiation which is responsible for the formation of the ionosphere—the highly ionized regions of our atmosphere between 100 and 300 km—which are able to reflect radio waves sent up from the ground, waves which carry important messages over large distances at speeds close to the velocity of light. The whole problem of long-range radio communication is affected by the state of the ionosphere.

An artificial satellite capable of measuring over an extended period of time not only the radiation entering the atmosphere when the sun is quiet, but also the radiation emitted during solar flares and during other solar disturbances, would be of vital help in our understanding of radio blackouts, and might provide a clue to the correlation of weather phenomena and specific solar activity. The continuous vertical shifting of the ionized layers with latitude, seasons, and time of day may be explainable from these observations, in which case better predictions for communication purposes could be made.

The methods used to detect solar radiation depend on the wavelength region of interest and on the altitude above the earth at which this radiation is to be observed. At an altitude of about 250 miles, practically the entire spectrum of radiation emitted by the sun and its atmosphere should be present.

Ultraviolet intensities have been measured by thermoluminescent phosphor, which has the property of being sensitive to wavelengths less than  $1300 \text{ \AA}$  but not above. X-ray radiation can be measured by photon counters. Telemetering devices and attitude control in a satellite would be necessary to obtain this information. For this reason, observations of this type may not be among the first to be made from an artificial satellite.

In concluding this presentation, I should like to stress the fact that important knowledge can be gained from observations made from any satellite, whether or not it carries an appreciable instrumentation payload. The experiences

gained by the designer and the constructor of the first satellite vehicle would add to the improvements in the ones to come. I am convinced that once we enter the satellite age, the possibilities for advancement in science and its application to commercial problems will be very great.

